Effect of Subcritical Crack Initiation on Hydraulic Fracture*

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Abstract

The challenge of a significant percentage of failed stages in multistage fracture stimulation of unconventional reservoirs is currently common among the operators across the Gulf region of the Middle East. The majority of these failures are caused by the inability to break down the rock subjected to high in-situ stresses with strong tectonic component. In addition to that, within the fractured stages, there are clusters that do not contribute to production. In our presentation, we discuss an alternative fracturing mechanism which can help addressing those two issues. Namely, we bring the laboratory evidences of the delayed initiation of hydraulic fractures under subcritical pressures, that at wellbore pressures insufficient to induce instantaneous breakdown. The delayed fracture initiation process is related to the so-called static fatigue which is observed in many quasi-brittle materials, including rocks, as a collapse which is delayed in time but will occur even if the applied stress is below the material strength. Our experimental results show that this time delay can be influenced by various factors, such as the fluid viscosity and acidity, and the confining stresses. Practically this means that fracturing fluid can be chosen to enable the initiation and growth of hydraulic fractures under conditions where the required wellbore pressure for instantaneous initiation cannot be reached. Numerical model accounting for the subcritical fracture growth - captured the experimental observations of the delayed initiation. The modeling also supported the delayed initiation mechanism to allow for a greater proportion of the clusters to be stimulated via the initiation of additional hydraulic fractures within the stage when the wellbore pressure starts to plateau or decline following the initiation of the first fracture.

Selected References


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Are there alternative fracturing mechanisms which can improve the ratio of successful stages?

Delayed fracture initiation, also known as static fatigue:

- Failure of the materials under loads that are insufficient to cause instantaneous breakage
- Observed in many materials, including, rocks but ignored in the current HF design models based on LEFM

Numerical model:

- 2D (plane strain or axisymmetric)
- Single or Multiple hydraulic fractures
- Impermeable, linear elastic fractures
- Fully-coupled with flow of viscous frac fluid
- Empirical law of subcritical crack growth when $K_c < K_{IC}$

Conclusions:

- Subcritical (delayed) fracture initiation may reduce breakdown pressure and completely change multiple hydraulic fracture growth compared to LEFM
- The effect is emphasized as delay time (exponent $n$) is decreased
- The latter can be tuned via chemo-mechanical fluid-rock interaction

**Figure:**

- Time to breakdown (sec) vs. Tensile Stress (Mpa)
- Borehole pressure is built up rapidly and held at the given target value. Time required to breakdown is measured.